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Compressed Air

DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

VOL. II. NEW YORK, MAY, 1897. No. 3

Editorials.

Relative Efficiencies of Compressed Air Plant, Due to Difference of Level above and below Sea.

A Municipal Power Plant.

Compressed Air.

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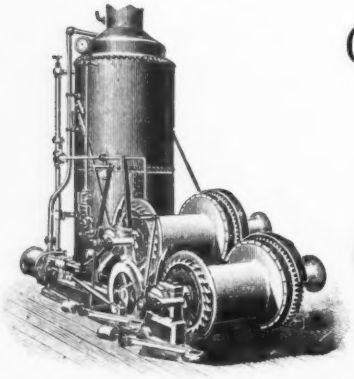

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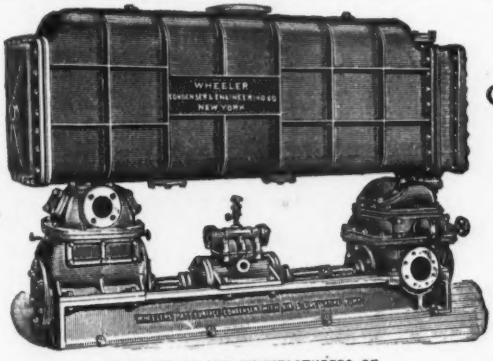

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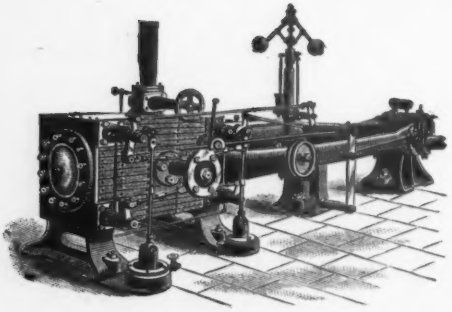

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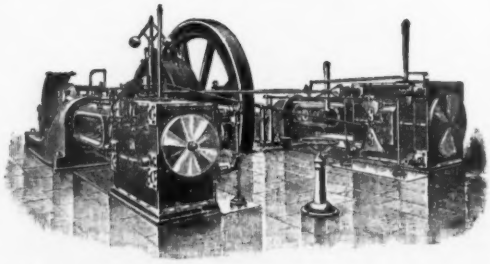

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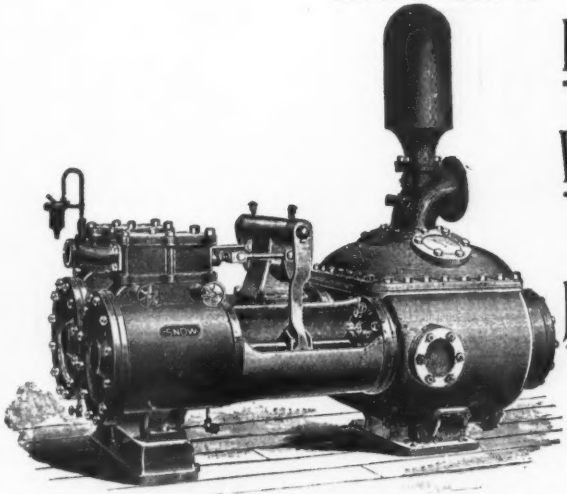

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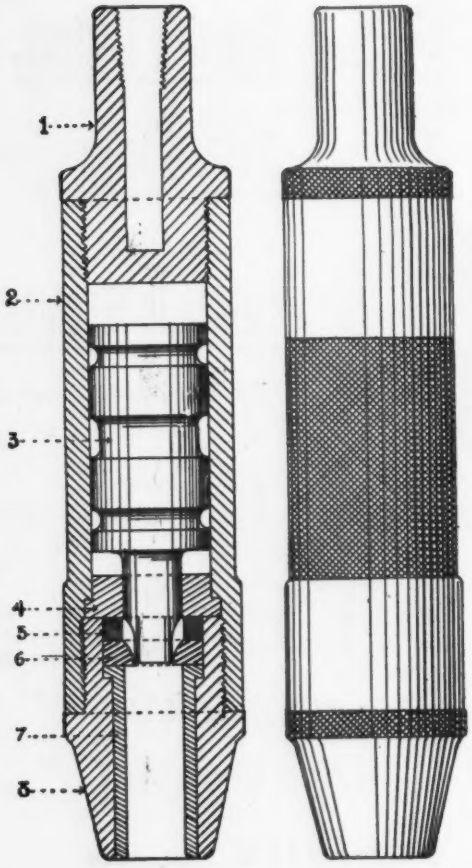

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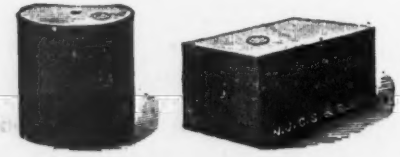

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Compressed Air.

A MONTHLY PUBLICATION DEVOTED TO THE USEFUL APPLICATION OF COMPRESSED AIR.

W. L. SAUNDERS, - - Editor and Publisher
A. E. KENNEY, - - Managing Editor
J. E. QUINTERO, F. C. WEBER, - - - - - Associates

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Advertising rates furnished on application.

We invite correspondence from engineers, contractors, inventors and others interested in compressed air.

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Those who fail to receive papers promptly will please notify us at once.

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VOL. II. MAY, 1897. NO. 3.

The Automatic Air Brake has been in service for so many years, and has been so faithful and punctual in performing the offices required of it, that we have come to look upon its prompt and efficient action as a matter which is of course to be expected. A little reflection upon the conditions under which it operates, however, will bring the conclusion that the certainty and reliability with which the automatic brake performs its work is one of the most remarkable characteristics of the apparatus.

In the first place, the orderly performance of the different operations of the automatic brake is entirely dependent upon the operation of a piece of mechanism called the triple valve, which requires unusual nicety of construction, and which, in some respects, requires the most careful adjustment. This valve mechanism consists of a number of moving parts, which must operate every time the brakes are applied, and every time that the brakes are released. The delicacy of the adjustments would appear to require careful watchfulness, considerate attention and reasonable protection. Yet this apparatus is secured beneath the floor of a railroad car which goes jolting over the road, is subject to constant vibration and concussion, and is subjected to the influence of a constant whirl of cinders, sand and dirt. These conditions are of themselves such as would seem to prohibit the successful use of a delicate piece of mechanism to be operated by small differences of air pressure. More than this, the neglect to clean and lubricate the frequently moving parts of this delicate mechanism has in many instances extended over years at a time, so that it would most naturally be expected that it would become so disordered as to entirely refuse to operate. Yet it has gone on, year after year, under these most trying conditions, performing the service required of it with promptness and efficiency to an extent that seemed to indicate to some that it really was unnecessary to give the apparatus any attention at all.

The continued reliability of the apparatus must be attributed, first of all, to unusual care in the selection of material, and to methods of special accuracy and refinement in manufacture. The prompt release of the brake depends, to a large extent, upon such a high character of material and workmanship, because the operation of the triple valves to release the brakes depends upon a small excess of air pressure upon one side of a small piston, which excess can be obtained but gradually, and would be impossible to obtain at all if any material leakage past the small piston occurs.

But the complete reliability of the apparatus for the application of the brakes is a feature of design and invention. The brakes are applied by dissipating the air pressure in the main air pipe which extends throughout the train, and, however much difficulty there might be in charging an efficient pressure into the pipe, there can never be any doubt of the ability to promptly discharge the air pressure, as it

merely requires an opening from the pipe to the atmosphere at any point. In this way a powerful pressure upon one face of the small piston of the triple valve may always be promptly rendered available for moving the piston into a position to apply the brakes.

Any uncertainties, therefore, as to the operation of the automatic air brake, which may arise from neglect and disorder, apply only to the release of the brakes, whereby the train may be enabled to proceed; but, once that the brakes are released and charged with air pressure, the prompt response of the apparatus to apply the brakes, at any time that they may be required, is assured and inevitable, as the only requirement then is that the train pipe shall be given an opening to the atmosphere.

Have you subscribed for COMPRESSED AIR? It is now in its second year and is diligently employed in advancing the useful application of compressed air. From it you get all that is valuable to know in compressed air practice. We gather compressed air information from all sources and place it before you in compact form to bind for reference. We would like to have your name on our list as a subscriber The cost is only $1.00 a year. Subscribe now.

MR. F. A. WALDRON, Superintendent Power and Plant of the Yale & Towne Co., Stamford, Conn., says in a recent letter to COMPRESSED AIR: "It may be interesting to you to know that two years ago we had about 100 to 150 feet of air pipe in our works, and this was for one purpose only. Now we have nearly a mile of air pipe, and use it for various purposes. From our experience here, we are of the opinion that the uses of compressed air will expand at a greater ratio than the air itself, and trust that the circulation of your lively little paper may increase at a greater ratio than either of the two above."

We invite our readers to send us communications regarding the use of compressed air and their experience with it. It is now largely used in mines and shops and many other places where least expected. The mechanical world will be interested to know what you are doing with it and how you are doing it. If you have data at hand that is the result of practical experience, or theories that you think should be applied, send them with drawings or photographs for reproduction. We are always glad to print anything of interest concerning air power. We again invite you to assist in promoting the use of compressed air, and we will give your contributions our best attention.

Relative Efficiencies of a Compressed Air Plant Due to Difference of Level Above and Below Sea Level.

The atmosphere surrounding the earth forms a layer extending about 45 miles in height, and being ponderable and very elastic, its density will vary with the height.

At the sea level the weight of a column of atmospheric air one square inch in area will balance a column of mercury 30" high one square inch in area, and corresponds to a pressure of 14.7 pounds per square inch.

Now, if we take the sea level as a basis for comparison as to the density or weight per cubic foot, we will find that the higher up we go the more rarified the air becomes, due to diminished height of the atmosphere above us, and by descending the shaft of a mine the contrary effect takes place. However, in the mine or in any level below the sea this contraction of the air is counteracted by the increasing temperature as we approach the centre of the earth.

From observations taken at different parts of the world this increase has been

found to average 1 deg. F. for every 61 ft. depth. The temperature also changes with increasing altitudes. However, since there is no uniform change in temperature throughout the world for points at the same elevation, it will be hard to estimate this effect generally, and in order to show this influence of temperature and pressure we must assume some specific case.

A motor using compressed air at full stroke and at 80 pounds per square inch, will require at any level either above or below the sea level—

$$\frac{229.5}{\left(1-\frac{p_a}{p_2}\right)p_a} = \text{cu. ft. free air}$$

per minute per I. H. P.

where p_a = atmospheric pressure

p_2 = absolute working pressure.

From a study of this formula it will readily be seen that as the atmospheric pressure diminishes, the cu. ft. free air required per H. P. will increase, and consequently a larger compressor will be required at an elevation than at sea level to enable the motor to do the same amount of work in a given time.

The relative efficiencies due to change of volume have been plotted in the curves shown on page 222. Both temperature and difference in levels above and below sea level have been taken account of, so that by reference to this chart it will be an easy matter to select an air compressor of sufficient capacity to supply a motor with an equivalent volume of air, no matter where it may be located provided temperature changes and working pressure are the same as assumed in the curves.

Thus, given an altitude of 6000 ft. above sea level, and provided the temperature at this level is the same as at the sea level, then by referring to the chart and reading along the 6000 ft. level line until we intersect the constant temperature curve, we will find by reading across to the right that the efficiency of an air compressor at this altitude is but 81.5 per cent. of its efficiency at sea level; and in order to produce the same efficiency, the free air capacity of compressor will have to be increased 18.5 per cent. When the temperature of the air changes proportionately from 62 deg. F. at sea level to 32 deg. F. at 10,000 ft. altitude, the efficiency in the case we have assumed will be 84.2 per cent. (as will be seen from the curves).

The efficiency at 2000 ft. below the sea would be 105.5 per cent., provided the temperature was constant (62 deg. F.); however, the rise in temperature of 1 deg. F. for every 61 ft. depth, exactly offsets the gain which might be effected by increased density, and therefore the efficiency is practically constant for all depths below sea level. (See curves.)

The change in volume due to different altitudes also effects the power required to perform a given amount of work. The mean effective pressure per cubic foot is less at an altitude than at sea level, but the number of cubic ft. required to produce the same effect at an altitude as at the sea level is more, and the product of the two (M. E. P. x Vol. = power expended), is greater. Curves on page 223 show the relative effect for the different altitudes and different temperatures. Thus at 6000 ft. and temperature at 62 deg. F. (same as assumed at sea level), the increase in power for a given effect will be 13.30 per cent. If the temperature changes proportionately from 62 deg. F. at sea level to 32 deg. F. at 10,000 ft. altitude, the increase in power will be but 8.8 per cent. The difference between both curves shows the benefit obtained from cold air.

F. C. WEBER.

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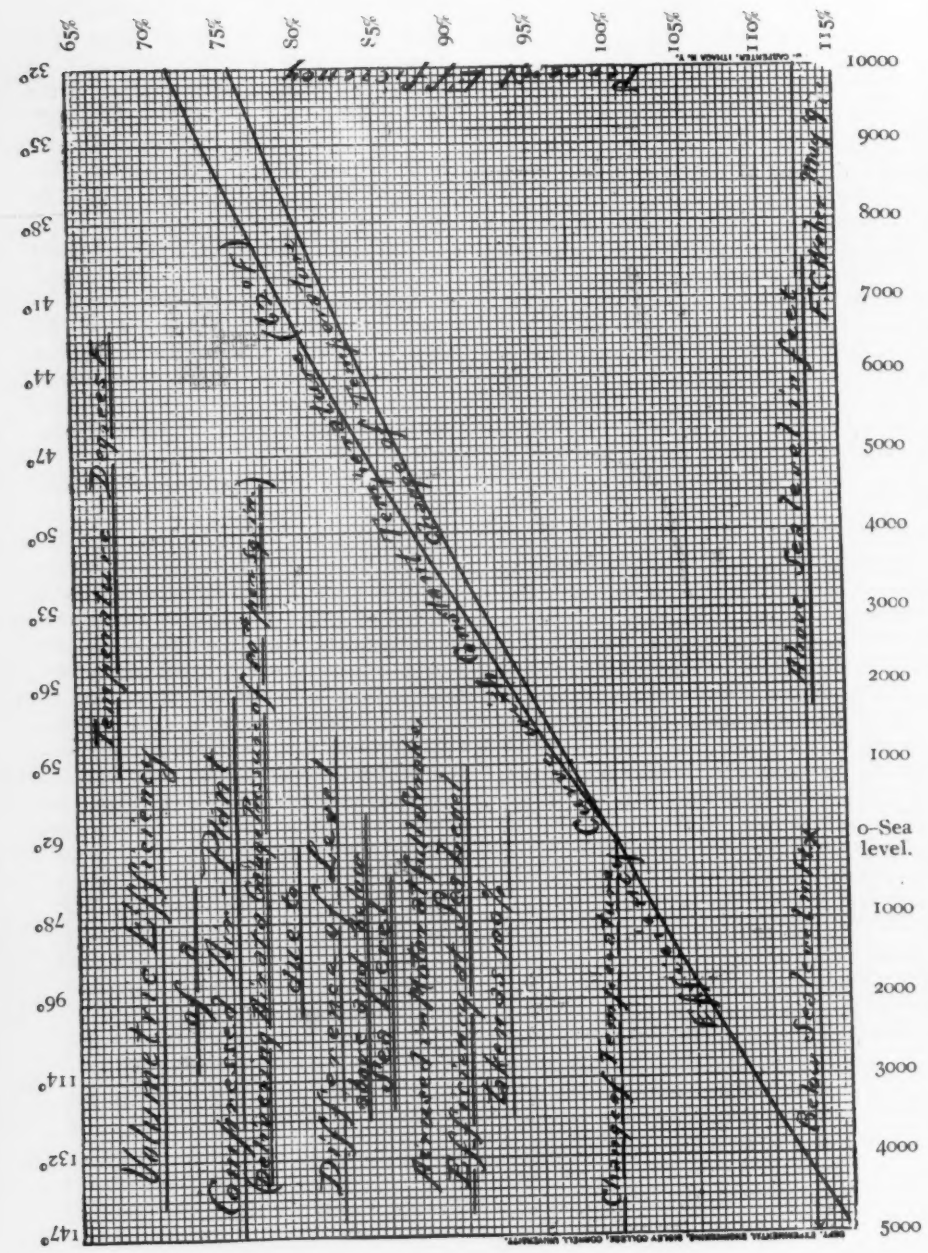
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44°
47°
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53°
56°
59°
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7000
6000
5000
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3000
2000
1000
0–Sea level.
1000
2000
3000
4000
5000
Temperature Degrees F.
Above Sea Level in Feet.
Below Sea Level in Feet.
Volume true Efficiency
Compressor Plant
Delivery Pipe
Receiver
Main
Distributing Pipes
Motor
Efficiency of Motor at Pulley
Efficiency of Plant
Delivery
Compressor
Motor
Change of temperature (62° F.)

Temperature Fahr.
Temperature Cent.
Curves of Pressure required to compress air to the pressure of the atmosphere at sea level, at various temperatures.
Percent of Power required to compress air to the pressure of the atmosphere at sea level, at various temperatures.
Percentage

A MUNICIPAL POWER PLANT.

The following paper on the "Transmission of Power by Compressed Air" was recently presented by Richard Hirsch, before the Engineers' Society of Western Pennsylvania, Pittsburg, Pa.

In papers presented to this Society at different times, various methods of transmitting power in the city of Pittsburg have been advocated. Up to the present time, however, the only agent which has been utilized for this purpose is electricity, unless we mention our city water supply, which has been used for hydraulic elevators, and in a few instances for motors operating light machinery.

It has been unfortunate for the reputation of compressed air that so little attention has been given to its development as an efficient transmitter of power. In most applications its peculiar advantages, such as safety, non-condensation during transmission, and unobjectionable exhaust, have been features of first consideration. Little attention was given to economical operation, inefficient compressors and wasteful motors being used. Compressed air has many advantages which entitle it to a more general recognition as an efficient means of transmitting and distributing power in cities.

In the use of steam, the loss by condensation in the pipe lines, the necessity for expensive pipe coverings and expansion joints, and the objectionable exhaust, either as steam or hot water, are disadvantages not met with in the use of compressed air. The high cost of hydraulic power, and the limited possible applications of the same, place it in an unfavorable light, when brought into competition with pneumatic transmission. The ease with which electric wires can be strung on poles, over housetops, and through buildings, and the low cost of such work, have been great factors in the rapid increase in the use of electrical machinery—much more so, in fact, than the cost of electric power. But vigorous protest should be made against the disfiguring of house fronts and interiors by the promiscuous array of wires, insulators and transformers. The conversion of our streets into veritable forests of unsightly poles, carrying net-works of highly charged and uncovered wires, should not be tolerated. When electric conductors are laid underground, and interior wiring concealed in the walls and floors of buildings and securely insulated, the cost of such work equals, if not exceeds, the cost of piping required for transmitting power by other agencies.

Compressed air is used at pressures varying from that of a more or less perfect vacuum up to 5,000 lbs. per square inch. There is a power transmission system in Paris where motors are operated by the pressure of the atmosphere and exhaust into mains in the streets, in which a more or less perfect vacuum is maintained by air pumps situated at a central station. Pressures of from 60 lbs. per square inch to 90 lbs. per square inch are used for ordinary power purposes; from 400 lbs. per square inch to 800 lbs. per square inch for pneumatic locomotives; 2,000 lbs. per sq. inch for street cars, and from 1,000 lbs. per sq. inch to 5,000 lbs. per sq. inch for pneumatic dynamite guns and other purposes on war vessels.

The gratifying results obtained in the use of compressed air for operating locomotives and shop machinery, and the high efficiency that could be obtained in a properly designed plant for the general transmission of power, lead the author of this paper to believe that such a plant could be successfully operated in the city of Pittsburg, considered both from an engineering aud business point of view. The following is a description of a proposed plant capable of transmitting 1,100 indicated horse-power, developed in the motors where used, with the cost of building and operating the same.

In a fire-proof building situated on the banks of one of our rivers, and as near the business portion of the city as possible, will be installed the necessary boilers and air compressors. Water for feeding boilers and cooling purposes will be pumped from the river, thereby saving water tax. Coal will be received by rail or boat, and handled by machinery. Ashes will also be handled by machinery, and loaded into boats or cars as required. Boilers will be of the water tube type, fitted with mechanical stokers, and capable of developing 2,000 indicated horse-power in the steam cylinders of the compressors. There will be two air compressors, with triple expansion condensing engines of the Corliss type, having steam cylinders 20", 34" and 50" diameter, by 42" stroke. The air cylinders will be compound, two for low pressure, each 26" diameter, and one for high pressure, 30" diameter; all 42" stroke. The air will be taken at atmospheric pressure through a cooling apparatus and specially

adapted Corliss valves into the two low pressure cylinders, and discharged through an inter-cooler, into the one high pressure cylinder; the air will there be compressed to 100 lbs. per square inch, and delivered through a cooler into the pipe line. Each compressor will be capable of delivering about 6,000 cu. ft. of free air per minute, compressed to 100 lbs. per square inch gauge pressure. The compressor will be fitted with automatic valves which will reduce their speed when the pressure in the pipe line runs up to a little more than 100 lbs. per square inch and speed them up again when the pressure falls. It might, however, be advisable to subdivide the compressing machinery into three or more units to facilitate repairing and lessen the liability of seriously crippling the plant in case of accident or breakdown. There is no necessity for large storage tanks or reservoirs, as the air mains provide sufficient capacity to permit the air to be pumped directly into them. Moisture will be withdrawn from the mains by suitably arranged traps and delivered into the sewers. These traps need be but comparatively small affairs, connected to the air mains by pipes of small diameter and enclosed in the street boxes with the shut-off valves. For the reason that watery or other vapors can not be compressed to a density greater than that due to their temperature, the watery vapor in the air would condense soon after compression, and most of it would be drawn off near the power house.

The main pipe line from the power house will consist of 12" wrought iron pipe coupled together by bolted flanges. It will extend to where the next work of street distributing mains begins, and will there be reduced in size as the carrying capacity and frictional resistance of each branch of pipe permits. The street distributing mains will consist of 6" and 8" wrought iron pipe coupled together by threaded sockets. No expansion joints will be required, as the mains being laid below the frost line, and the air being cooled after compression in the power house, there will be no more variation in the temperature of the air mains than there is in water or gas mains, neither of which are provided with expansion joints. The expansion joints on the underground steam lines of the New York Steam Heating Co. are quite elaborate and very expensive affairs, and are placed at close intervals. In connection with pneumatic locomotives, wrought iron mains with screwed sockets and without expansion joints are used, carrying pressures of from 400 lbs. per square inch to 700 lbs. per square inch. The satisfactory results obtained in the use of these lines furnish a precedent for advocating street distributing mains of practically the same description, although various other kinds of joints have been used in Paris and elsewhere for this purpose.

In the Paris system, steel mains 20 inches in diameter are used, having perfectly plain ends and connected together by the so-called Normandy joint, which is described in Unwin's Development and Transmission of Power.

In estimating the cost of construction it has been assumed that the power station could be located within 8,000 feet of Eleventh or Grant streets, and allowance has been made for that length of 12 inch main. Provision has been made for laying pipes on all the principal streets of Pittsburg situated between the Monongahela and Allegheny rivers and on and below Grant and Eleventh streets. Stop valves inclosed in suitable street boxes will be provided at frequent intervals in the mains, by means of which the air supply can be shut off from any section of pipe undergoing repairs, or while service connections are being made. At such times the air can be made to pass the portion of the main thus cut out, through the pipes in the adjoining streets, causing inconvenience to but few users of the power. Much annoyance could be averted by making service connections at night, or if made by day, appliances could be used which permit making connections to pipe lines without shutting off the supply. The estimate does not cover the cost of service connections, as they will be paid for by the consumers of the power, but does cover the cost of meters. Liberal margin has been allowed in the various items, and the following figures would undoubtedly cover the actual cost of construction. Allowance has been made for dividing the boilers and compressors into such units as to provide reserve power, available in case of accident or while repairs are being made.

COST OF CONSTRUCTION.

Real Estate	$ 30,000 00
Buildings	20,000 00
Compressors erected on foundations with Condensers and attachments	55,000 00

Boilers	21,000 00
Stack and Britchen	3,750 00
Mechanical Stokers	4,375 00
Circulation and Feed Pumps, Injectors, etc.	4,000 00
Cooling Apparatus	2,000 00
Water Tanks	1,500 00
Coal and Ash Conveyors	4,000 00
Pipe Lines and Distributing Mains	70,000 00
Meters	5,000 00
Engineering and Expenses of Organization	25,000 00
Miscellaneous Items, including electric light plant and crane for power station	10,000 00
Contingencies	19,375 00
Total cost of plant	$275,000 00

COST OF OPERATION PER ANNUM.

Interest on investment of $275,000 at 6 per cent.	$ 16,500 00
Deterioration 4 per cent. of $275,000	11,000 00
Taxes	3,500 00
Fuel	5,000 00
Salaries and Wages	16,500 00
Repairs and Supplies	5,000 00
Office Expenses	2,500 00
Total annual cost of operation	$ 60,000 00

It is estimated that the plant will deliver 1,100 H. P. for 3,000 hours, and 200 H. P. for 5760 hours per annum, or a total of 4,452,000 H. P. hours per annum. The annual cost of operation, divided by 4,452,000, gives 1.35 cents per H. P. per hour, or $40.50 per H. P. per annum of 3000 hours.

The cost of power to consumers would be graded somewhat, according to the amount used. This would not be a hardship to small users of power, because to such consumers the power would be cheap at any reasonable price. To users of power in moderate quantities, the cost per H. P. per annum, including attendance, cost of heating and interest on cost of motors and heaters would not be more than $50.

For deterioration there will be laid aside each year out of the earnings, 4 per cent. of the total investment, and this money placed at 3 per cent. compound interest will, in about 19 years, equal the capital invested, or sufficient to rebuild the plant entire. It will be noted that the cost of operation would increase but slightly with considerable increase in the capacity of the plant, and also that the cost of construction would not increase in direct proportion to such enlargement of the plant. If the building of a larger plant would be justified, the cost of power to consumers would be less than given.

To compare the cost at which power could be furnished by compressed air with the cost as furnished by other means, I extract the following from our procedings, being estimates given in papers read by members of this society at different times:

Amount per H. P. per annum paid to the City of Pittsburg for operating hydraulic elevators (about)	$700 00
Cost of power per H. P. per annum in a large store having its own plant, 15 hour service	128 44
Cost in same plant corrected for 10 hour service	89 92
Estimated cost per H.P. per annum at which power could be furnished by a proposed hydraulic power company, with no allowance made in operating expenses, for taxes, or deterioration of plant	77 70
Cost in same plant corrected for above omissions	100 20
Estimated cost per H. P. per annum at which power could be furnished by an electric power company capable of delivering 20,000 H. P.	50 00

The low cost at which power can be furnished by compressed air can only be approached by electricity working under the most favorable conditions. The rates paid for power to the electric companies in Pittsburg at the present time are excessive.

EFFICIENCY OF THE SYSTEM.

It can be shown theoretically, and has been proven in practice, that one cubic foot of free air, when compressed to about 90 pounds per sq. in., is capable of performing from 2,600 foot pounds to 3,000 foot pounds of work, when used cold. From actual tests it has been found that by heating the air this can be increased 40 per cent. Prof. Unwin states that the experiments of Reidler and Gutermuth show that heat thus applied is used five or six times more efficiently than if used in a good steam engine. The compressors, as above specified, have a combined capacity of 12,000 cu. ft. of free air per minute. Deducting 15 per cent. of this for loss by leakage and friction in pipes, we have 10,200 cu. ft. of free air available for use-

ful work; or expressing it in foot pounds per minute, we have 10,200+2,600+1.4= 37,128,000; or in horse power, we have 37,128,000÷33,000=1,125 H. P., which is 56 per cent. of the indicated H. P. in the steam cylinders of the compressors; assuming the efficiency of the motors where the power is used to be 90 per cent., we have an efficiency of over 50 per cent. in the entire system, from the indicated horse power in the steam cylinders to the brake horse power in the motors. This compares favorably with electric transmission, which under average conditions is about 58 per cent. Much higher efficiencies than 50 per cent. have been given by writers on this subject, but the figures here given are based on the actual capacity of the compressors after due allowance has been made for internal friction and other unavoidable losses, such as leaking stuffing boxes, valves and pistons; and more especially the loss occasioned by the heating of the air during compression. Moreover, the builders of the compressors will guarantee the capacity as here given, and the estimates from two different firms showed practically the same indicated horse power in the steam cylinders of the compressors to produce the amount of air required.

One thing to be noted in the use of compressed air is the fact that the loss caused by the fall in pressure resulting from friction in the mains, is partly made up by the increase in volume. In a hydraulic system a fall in pressure, caused by friction in the mains, results in a loss in direct proportion to the fall in pressure; the volume remains the same. The efficiency of the system can be considerably increased by using compound motors, in which the air would be heated before entering the motor and reheated between the first and second expansions; the motor being somewhat similar to a compound steam engine with a receiver between the high and low pressure cylinders, the receiver in this case being a reheater. When the air is heated to increase the economy, the most efficient results are obtained when moisture is added, which by giving out its latent heat in the motor, materially increases the efficiency. For this reason heaters are generally of the hot water style, wherein the air passes through hot water under pressure, and part of it goes to the cylinder of the motor in the form of steam.

USES OF COMPRESSED AIR.

Compressed air can be applied to such a wonderful variety of uses that a ready market for the entire power of the plant is almost assured, and the project would undoubtedly be as profitable in a financial way as it has been elsewhere, notably in Paris. The power would be used for the operation of elevators, electric light plants, ventilating apparatus, pneumatic tools, and motors. It would also be used for parcel and cash conveyors, cleaning and cooling purposes; for the latter purpose either air direct from the mains, or exhaust air from the motors, would be used. For comparatively small addition to the cost of building the plant, a system of regulating clocks could be installed, and but very little power would be required to operate it. Some of the new office buildings in the East have been piped for delivering compressed air to the tenants, the same as they would be provided with hot and cold water. Compressed air only lacks the capacity to supply heat, to enable it to operate the entire mechanical plant of the modern office building. Heat would be supplied by the boilers in the building, but not being called upon for lighting or power purposes, would be operated only during the cold months of the year. In the ideal plant, however, heat would be furnished by the hot water system, and power and light by air—the cost of operation being thereby reduced to the minimum.

The project could be still further enlarged upon. While laying the distributing main, ducts could be laid for a parcel delivery system. Stations would be located in different portions of the city, where parcels would be received and sent through the chutes to the station nearest to the destination of the package, and the delivery be completed by messenger.

It would be practicable to have street connections in close proximity to the fire plugs, and operate fire engines by air, which could then be built much cheaper, lighter in weight, less complicated in detail, and would be ready for immediate service at all times. In fact, the practicable applications of the power are almost unlimited, and the project would certainly meet with success and pay handsomely on the capital invested. It would increase our business and manufacturing facilities and assist greatly in making Pittsburg a cleaner city and more desirable as a place of residence. These are factors in the making of a truly Greater Pittsburg. The building of a metropolis must consist of a more healthy and substantial growth than

accrues from the annexation of surrounding villages and pasture fields.

PNEUMATIC LOCOMOTIVES.

Compressed air has been used with great success in the operation of locomotives. When used for operating street cars or for hauling trains through tunnels or city streets, all the advantages of an independent motor are obtained, with none of the objectionable features of steam locomotives or electric cars. It is especially applicable in locations where sparking electric wires, fire and fumes of combustion must be avoided.

The following is a very brief description of the plant of the Susquehanna Coal Co. at Glen Lyon, Pa., where there are two motors in operation. The air is supplied by a compressor of the three stage type, having steam cylinders 20 inches + 24 inches, and air cylinders 12½ inches, 9½ inches and 5 inches + 24 inches, with water jackets and intercoolers, compressing the air to 600 lbs. per sq. inch. The air passes through a line of 5 in. special strong pipe 200 ft. to the head of the shaft, down the shaft 800 ft. and then along the gangway about 3,400 ft., a total length of 4,300 ft. This pipe line has a capacity of 580 cu. ft., and acts as a reservoir for the compressor. It is coupled together with threaded sockets which are counter-bored for a lead filling which is caulked. At intervals of about 200 feet, and at all valves and charging stations, flange couplings are used with lead gaskets, and the line is perfectly tight, being tested to 1,500 lbs. per sq. in. Charging stations are placed where required, and consist of a universal metallic coupling, which is attached to the check valve of the locomotive air tanks when a fresh supply of air is required. It requires abont 1½ minutes to complete the operation of charging the locomotive, and reduces the pressure in the main pipe line from 600 lbs. per sq. in. to about 570 lbs. per sq. in. A charge of air weighs about 380 lbs. The locomotive is of the 4 wheel type, having cylinders 7 in. diameter by 14 in. stroke; drivers, 24 in. diameter; weight, 18,500 lbs.; length over all, 17 ft. 6 in.; width, 5 ft. 2 in.; height, 5 ft., 0 in. The air for propelling the locomotive is stored in two cylindrical steel tanks with a combined capacity of 130 cu. ft., and are supported by cast iron saddles resting on the frames of the locomotive. The air flows from the main tanks through a specially designed reducing valve into an auxiliary reservoir, and from thence through a throttle valve to the cylinders. The pressure in the auxiliary reservoir can be regulated anywhere from 30 lbs. up to 140 lbs. or 150 lbs. per sq. in., as required. The air in the auxiliary reservoir is maintained at a constant pressure, while in the main storage tanks it may vary from 570 lbs. per sq. in. down to the pressure at which the reducing valve is adjusted; when this pressure is reached in the main storage tanks, the air passes through to the cylinders without further reduction in pressure.

The locomotive hauls 16 empty cars a distance of 3,700 ft. into the gangway and returns to the shaft with 16 loaded cars with one charge of air, starting with a pressure of 575 lbs. per sq. in., and ending with about 100 lbs. per sq. in. The train of empty cars, including the locomotive, weighs 60,000 lbs., and the train of loaded cars, including the locomotive, weighs 166,000 lbs. The grades favor the loads. The locomotive runs from 25 to 50 miles per day, depending upon the length of the trip and time consumed in making up the trains at the terminals. This locomotive was lowered down the mine shaft a vertical distance of 800 feet without dismantling in any manner. Sometimes the circumstances are such that it becomes necessary to take the locomotive apart, lower it piece by piece, and reassemble them in the mine.

Where it is practicable to use a heater on a locomotive, the efficiency is increased about 40 per cent. These heaters take the place of the auxiliary reservoir, and consist of a tank containing hot water under pressure at a temperature of about 300 deg. F., through which the air passes before going to the cylinders. The heaters are charged with steam while the storage tanks are being charged with air.

Compressed air is also used for the propulsion of street cars, the air being stored in nests of Mannesman tubes. There are four of these tubes under each car seat, and are 9 inches in diameter by 15 ft. long, and are charged to a pressure of about 2000 lbs. per square inch. The air is reduced in pressure by a reducing valve to about 140 lbs. per sq. in., and then passes through a hot water heater and throttle valve to the cylinders. The cars are of the four-wheel type, have the ordinary street car body, and are provided with the usual locomotive machinery, reversing gear, balanced valves and air brakes. They can be controlled from either platform by means

of a fixture similar in appearance to a trolley car controller, and very compact. They are independent motors, have all the advantages claimed for storage battery cars, and compare favorably with the overhead trolley system in cost of operation.

COMPRESSED AIR.

(CONTINUED.)

In connection with a series of tests of a Baldwin compound locomotive upon the Baltimore & Ohio R.R., in 1890, the consumption of steam in various incidental ways was ascertained. The weights of steam which passed through the whistle, the blower and the pop valve, were computed. Instead of allowing the pop valve to blow off, a vent pipe from the steam dome was carried into the tender, and the weight of steam which would pass through it per second, when a valve in the pipe was opened, was ascertained. During the runs, when the steam reached such a pressure that the pop valve was on the point of blowing off, the valve in the vent pipe was opened, and, by noting the length of time that it remained open, the quantity of steam which so escaped was easily computed. The number and lengths of blasts of the whistle were also noted, together with the time that the blower was used. The amount of steam used by the 8-inch air-brake pump was also computed. It was found that, after the train brake apparatus had become fully charged, the pump continued to run with an average speed of about 62 strokes per minute. This would seem to indicate a considerable amount of leakage in the train pipe and connections. The writer has observed the operation of the 8-inch pump upon a considerable number of different trains, the air brake apparatus of which was in such condition as he happened to find it. It was found that, after the brakes had been charged throughout the train, the number of strokes per minute made by the pump were from 24, for a four-car train, to 47 for a seven-car train, the average of all the cases observed being 36.

During the trials of the Baldwin compound, three separate runs were made from Baltimore to Philadelphia, with the same train, making the same time, and with the same number of scheduled stops. In the report of Mr. George H. Barrus, the steam used in different ways during these runs was computed as follows:

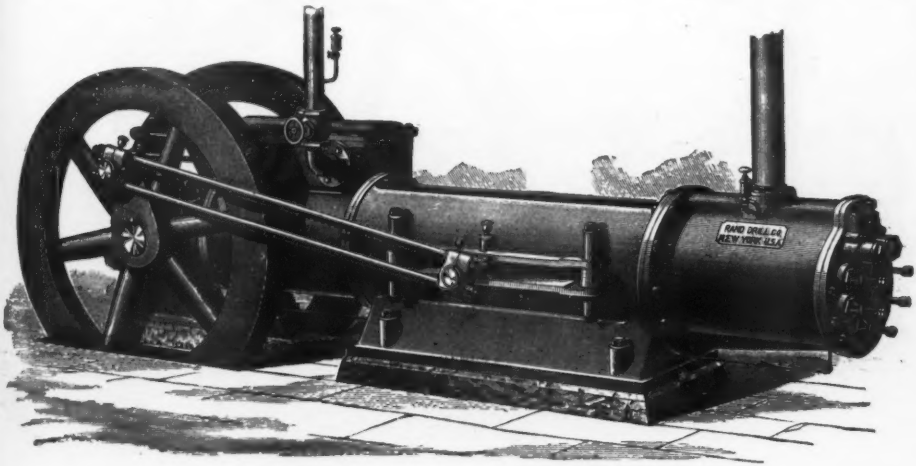

FIG. 19.—DIRECT ACTING STEAM AIR COMPRESSOR.

	Whistle.	Blower.	Safety Valve.
	415 lbs.	153 lbs.	220 lbs.
	503 lbs.	198 lbs.	99 lbs.
	425 lbs.	72 lbs.	302 lbs.
Average,	448 lbs.	141 lbs.	207 lbs.

The average computed steam consumption of the air pump, under the conditions of its actual operation, was 690 lbs. Under the ordinary conditions of the brake apparatus in service, with the air pump making

about 36 strokes per minute to keep up the pressure after the apparatus is once charged, the steam consumption, computed upon the same basis as that used in the report of these locomotive trials, would have been 400 lbs. It will be seen from these figures, therefore, that about the same quantity of steam was used by the whistle as is used by the air pump, and that, even in these locomotive trials, where unusual care was undoubtedly exercised in firing, the loss of steam by the safety valve was about half that which should be used by the air pump.

Under the ordinary conditions of service, although the steam used by the air pump is largely that which would otherwise be lost at the safety valve, it is most probable that the amount of steam lost at the safety valve is greater than that used by the air pump.

It will thus be understood that, with the fluctuating conditions of locomotive service, the steam consumption of the air-brake pump is an insignificant factor in the economy of steam production. It has never been demonstrated, so far as the writer is aware, that a locomotive hauling an air-braked train, with the brake apparatus in ordinarily good condition, consumes, in the long run, a pound more coal than the same locomotive, without an air pump, would use in hauling the same train when braked by hand, and there is no good reason to believe that it would.

Fig. 19 illustrates the simplest type of small air compressor built on the Straight Line or Direct Acting plan. The machine is designed for light transportation and for use in places where a compact, self-contained and very simple compressor is wanted The steam and air cylinders are connected to a crosshead which moves in guides arranged between the cylinders. The fly wheels, which are joined by connecting rods to this crosshead, are mounted in bearings close to the steam cylinder. Slide valves are used operated by eccentrics, though in some of the larger sizes the adjustable cut-off serves to aid this type of machine in fuel economy. The air cylinder is provided with poppet inlet and discharge valves, and is water jacketed. Simplicity of design is followed in machines of this type, no claims being made to high fuel economy.

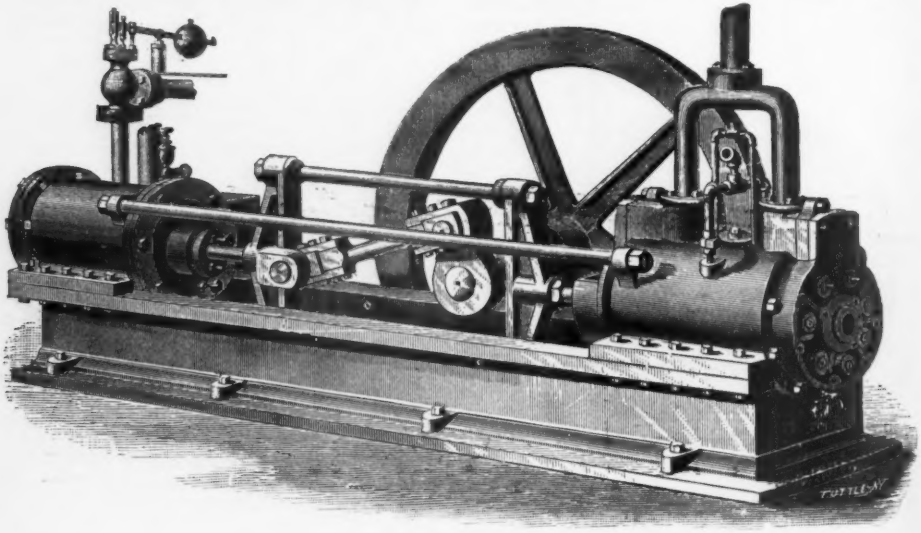

FIG. 20.

Fig. 20 shows another type of simple, low cost, single or direct acting compressor. No crosshead is used. A single fly wheel with crank shaft and connecting rod are placed between the cylinders.

Fig 21 is shown for the purpose of illustrating the English type of single or straight line compressor. The machine shown is known as "Schram's patent." A

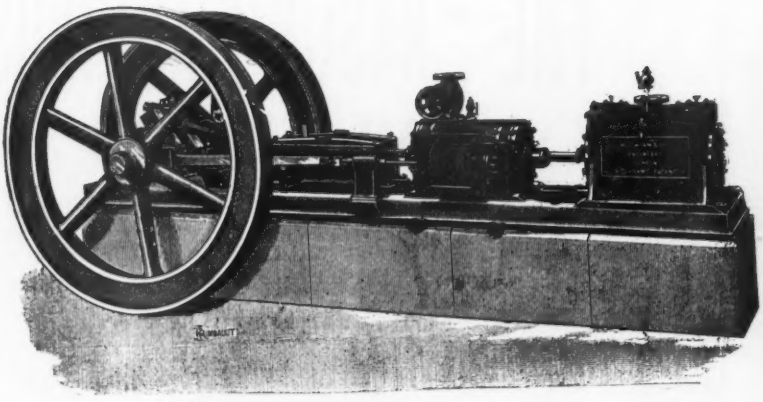

FIG. 21.

single cast iron bed plate is used, thus making the machine self-contained, and the fly wheel's crosshead and connecting rod are placed on the bed, the steam cylinder being located between these parts and the air cylinder. This construction brings the steam and air cylinders close together, but the machine is not as compact or as simple as the direct acting compressor of the American type.

Another form of European compressor on the straight line plan is shown in Fig. 22. This machine is made by Messrs. Burckhardt & Co., Basel, Switzerland. The steam and air cylinders are widely separated and are connected by a single piston rod joined at or near its centre by a crosshead, to which the connecting rod is attached.

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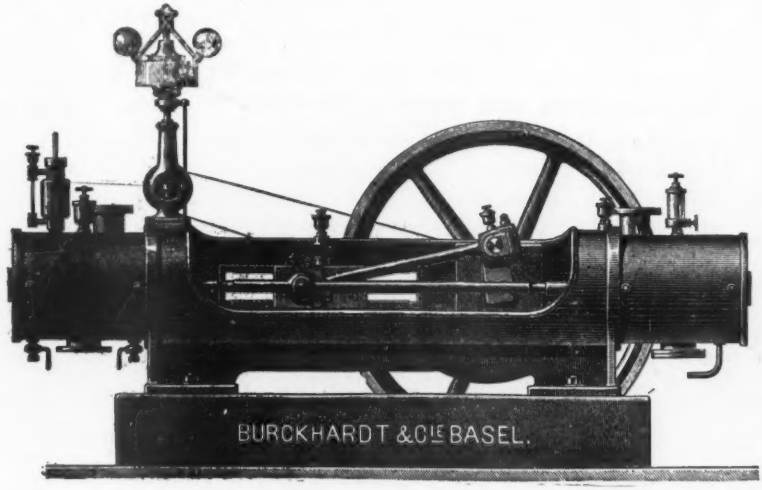

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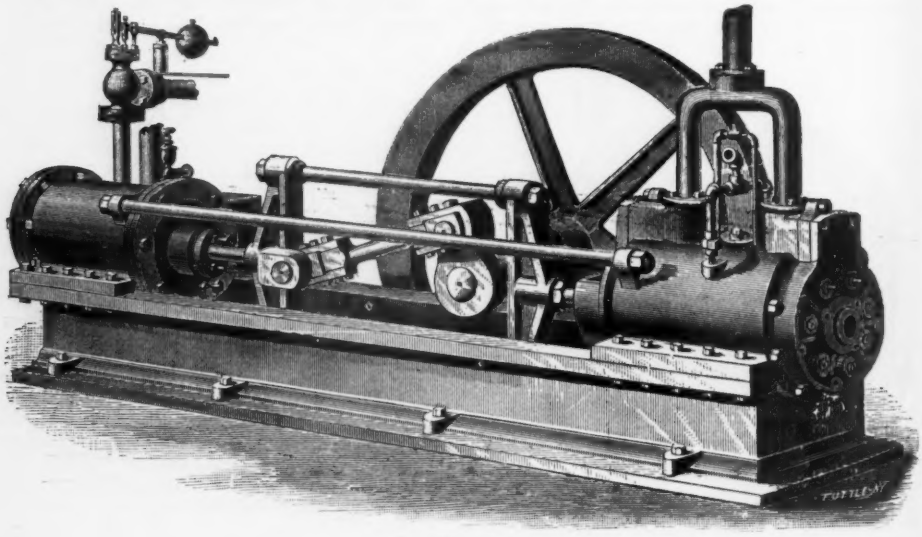

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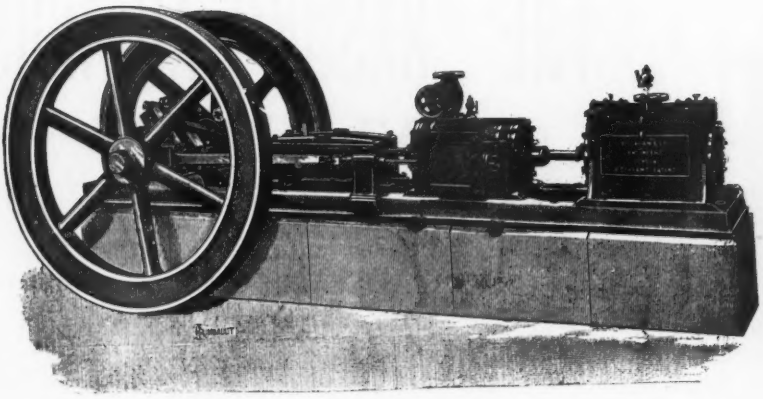

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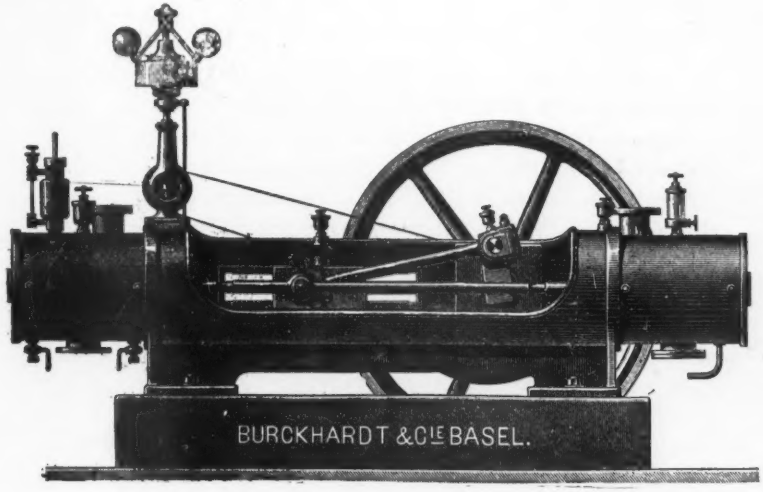

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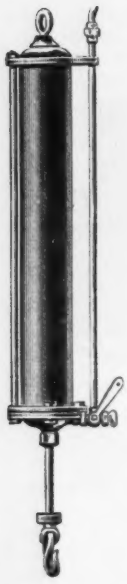

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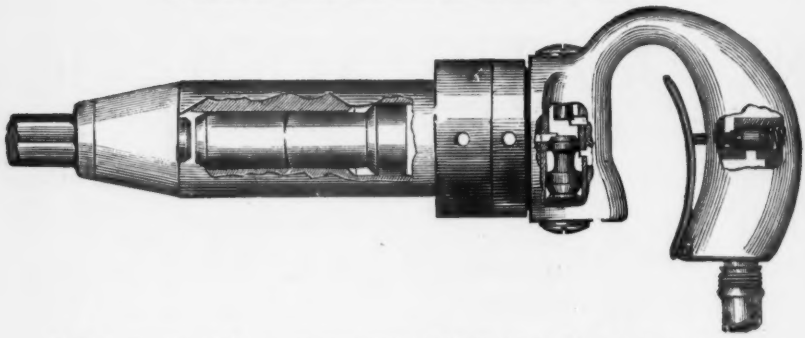

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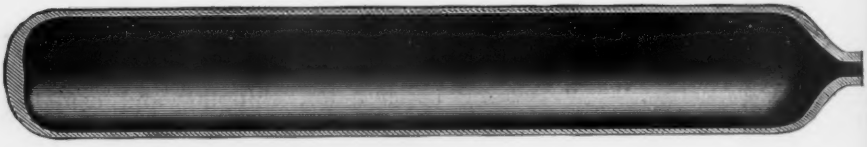

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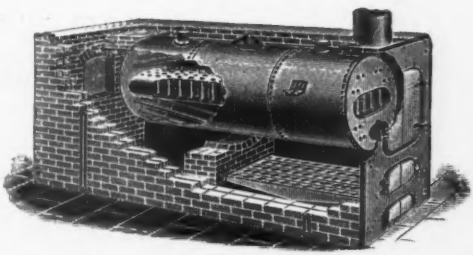

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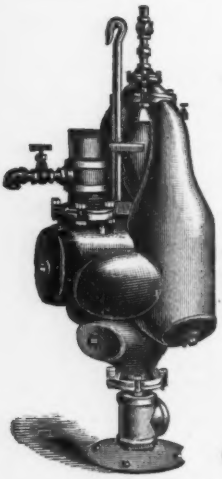

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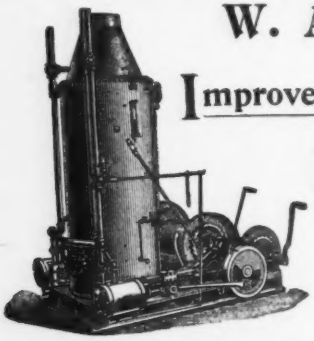

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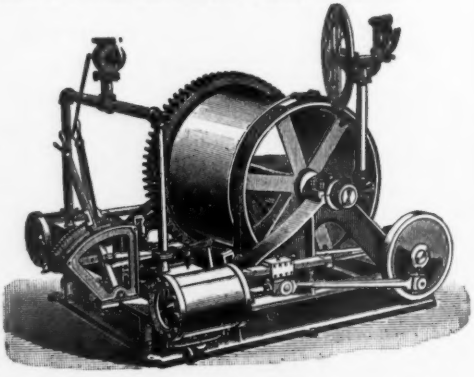

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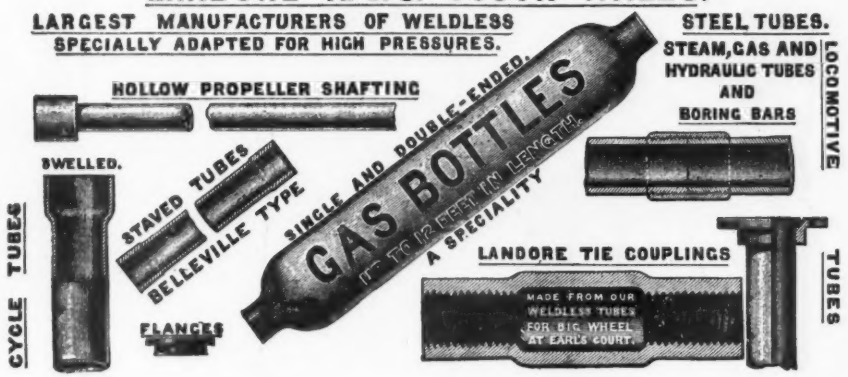

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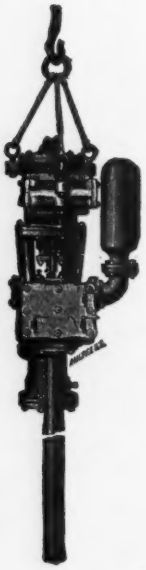

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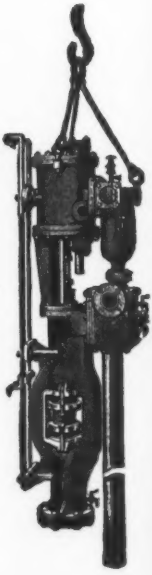

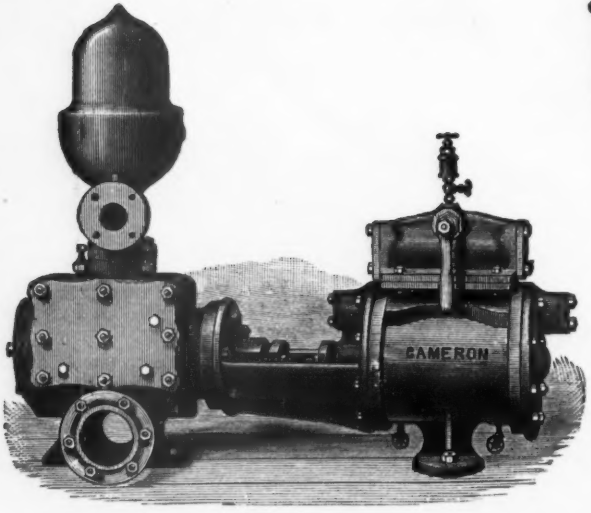

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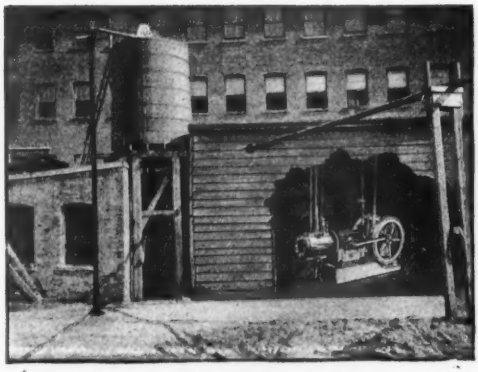

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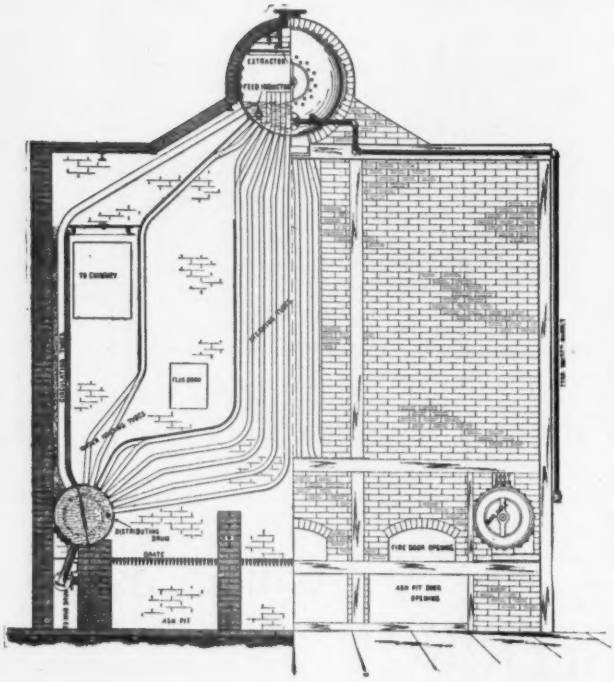

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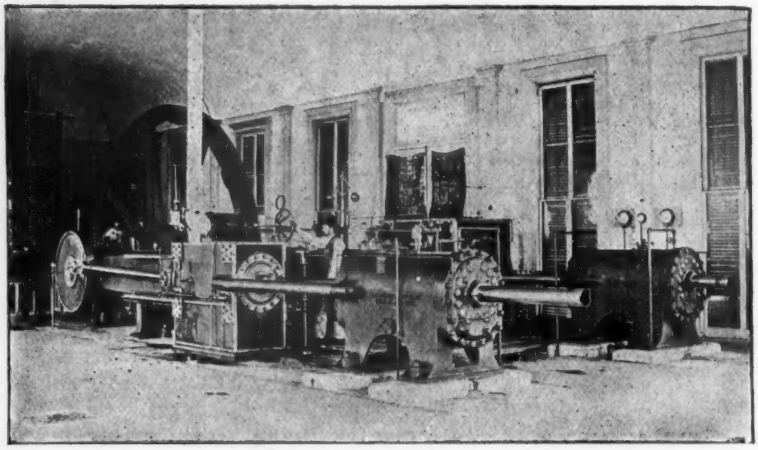

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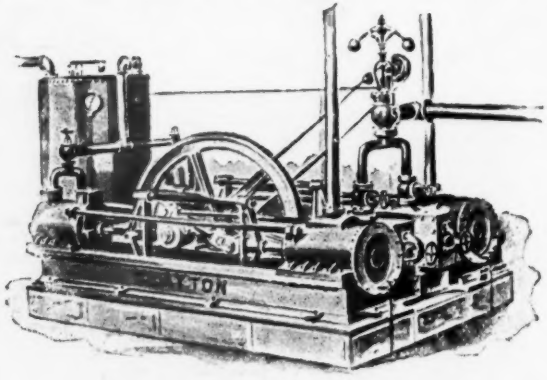

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